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SYNOPSIS AND CRITIQUE OF THE AVAILABLE FORECASTS OF SOCKEYE SALMON RETURNING TO BRISTOL BAY IN 1983

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ABSTRACT

This report reviews forecasts of the return of sockeye salmon to Bristol Bay, Alaska in 1983 made by the Alaska Department of Fish and Game (ADF&G), Japan, and the Fisheries Research Institute at the University of Washington. Individual ADF&G river system forecasts by age class are discussed in detail, and issues involving forecast reliability and consistency are addressed.

INTRODUCTION

This report is a synthesis of several independent forecasts of the returns of sockeye salmon to Bristol Bay in 1983, together with confidence intervals, relative accuracy, and a critique of each forecast method. The forecast methods considered are: (1) The standard forecast made by the Bristol Bay research staff, Alaska Department of Fish and Game (ADF&G); (2) A forecast made based on the arithmetic mean catch per effort (CPUE) from variable mesh gillnet sampling by Japanese research vessel south of the Aleutian Islands; (3) A forecast made based on the geometric mean catch per effort from variable mesh gill net sampling by Japanese south of the Aleutian Islands; (4) A forecast based on a relation between estimated total Bristol Bay parent escapement, mean June air temperature at Cold Bay during the two years prior to year of return and total Bristol Bay return; and (5) A forecast based on catch per effort in purse seine sampling south of Adak by the Fisheries Research Institute, University of Washington (FRI). Throughout this paper the Gilbert-Rich method of age designation for salmon is used[1].

METHODS

Standard ADF&G Forecast

The ADF&G forecast attempts to forecast by river system and major age class (4_2, 5_3, 5_2, 6_3) within river system based on a variety of techniques. The first method assumes a return per spawner based on either a river system specific escapement-return relationship or recent observed return-per-spawner estimates for the particular river system. The predicted returns from the parent escapement (1977, 1978, and 1979 brood years) based on the assumed return per spawner are partitioned into component age classes by the historical mean or cyclical mean proportion of the particular age class returning. This method is hereafter referred to as forecasting by return per spawner. The second method is based on the return of younger sibling age classes from the same brood year. Two techniques are used: The first uses a linear regression model of the forthcoming return of the older sibling age class based on the return of the younger sibling age class the year before, fit to historical data. In the second technique the return of the younger sibling age class is multiplied by the ratio of the return of the older sibling age class to the return of the younger sibling age class. These techniques are hereafter referred to as the method of forecasting by the return of sibling age classes. The third method is based on smolt studies. These studies are available only for the Kvichak and Wood River systems. There are three techniques used: The first multiplies the estimated number of smolts leaving the river system by the mean proportion surviving to returning

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[1] Gilbert-Rich Formula - Total years of life at maturity (large type) - year of life at outmigration from freshwater (subscript).

adults. For 4_2 and 5_3 age classes in the Kvichak River the proportion surviving is positively correlated with mean June air temperature at Port Heiden during the year of smolt outmigration (Yuen 1979). The proportion surviving for these age classes is appropriately adjusted for year to year variation in temperature based on simple linear regression. The second technique of forecasting based on smolt studies is the product of the numbers of outmigrating smolts, the average marine survival, and the average ocean age proportion. In the Wood River system the ocean age proportion is very close to the ocean age proportion of the parent escapement of the smolt outmigration and is used as the estimate of the ocean age proportion of the returning adults from the population of smolts outmigrating. The third technique of forecasting based on smolt data is the product of the fresh water age proportion of the smolt outmigration observed from the brood year of interest, the expected return from the brood year based on return per spawner, and the mean ocean age proportion. These techniques will be hereafter referred to as the method of forecasting based on smolt data.

Thus, several methods are available for forecasting returns for each river system and age class within river system. The results of each of the major methods (i.e., forecasting by return per spawner, return of sibling age classes, and smolt data), if available, are simply averaged and therefore weighted equally. If more than one estimate is available within a major method, these are averaged to give one result for the major method. In some cases a result for a major method is excluded in the final averaging process. The rationale for these exclusions is detailed in a separate section of this report.

Forecast Based on Japanese High Seas Sampling

The Japanese have been sampling a series of stations south of the Aleutian Islands during the summer months June through early August with variable mesh gillnets since 1972 (Takagi and Ito 1980). These catch data may be used to estimate relationships between mean catch per effort of 1-ocean[2] immature and 2-ocean immature and subsequent return of 2-ocean mature and 3-ocean mature sockeye salmon to Bristol Bay the following year, respectively (Figure 1). Two methods for analysis of the catch data have been used. The first method uses the arithmetic mean of the catch per effort among sampling stations and the second method uses the geometric mean per effort among sampling stations. The arithmetic mean was used in the ADF&G's analysis of and forecast based on the Japanese data (Yuen 1982) and the geometric mean was used in FRI's analysis of and forecast based on the Japanese data (Rogers 1982).

Forecast Based on an Escapement-Temperature Model

An empirical model relating observed returns to estimated parent escapement and mean June air temperature at Cold Bay during the period of ocean residence of the returning fish has been developed by Huttenen et al. (in prep.). The following model was used:

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[2] One marine annulus.

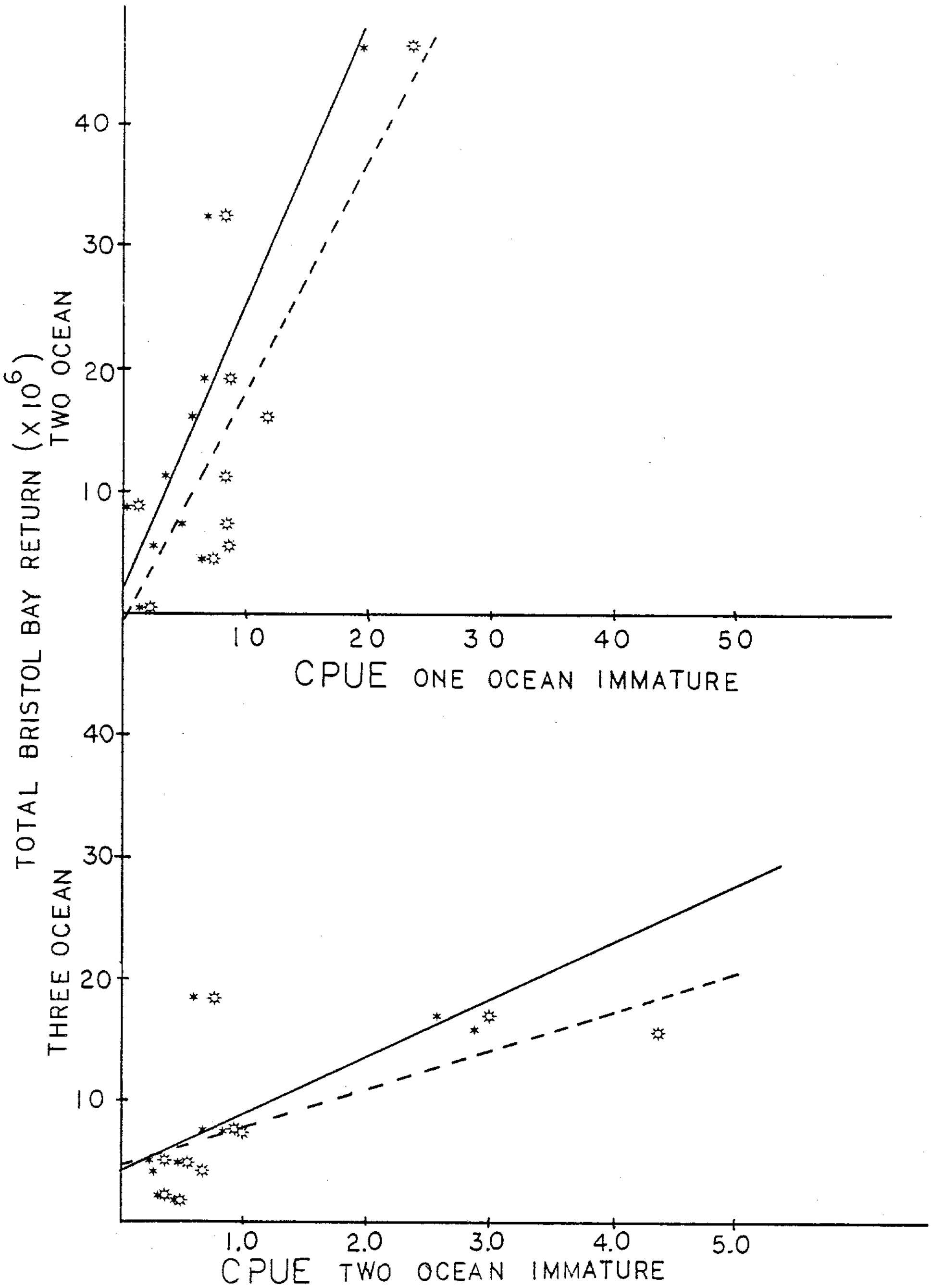

Figure 1. Upper panel - Relation between geometric mean CPUE of 1-ocean immature sockeye salmon from gill net sampling by Japanese and 2-ocean inshore return of sockeye salmon (solid line, closed stars). Y = A + BX, A = 1.650, B = 23.591, R^2 = .745, n = 10. Relation between arithmetic mean CPUE of 1-ocean immature (dashed line, open stars). Y = A + BX, A = -1.146, B = 19.094, R^2 = .672, n = 10. Lower Panel - The same for relation between mean CPUE of 2-ocean immature sockeye salmon and inshore return of 3-ocean mature sockeye salmon. Geometric mean is solid line, closed stars. Y = A + BX, A = 4.123, B = 4.739, R^2 = .513, n = 10. Arithmetic mean is dashed line, open stars. Y = A + BX, A = 4.526, B = 3.215, R^2 = .471, n = 10.

$$ln(R_i) = A + B_1\, ln(E_i) + B_2\, ln(T_i)$$

where R_i = returns in year i, E_i = the estimated parent escapement of the returns in year i, T_i = the mean of the two mean June air temperatures at Cold Bay during year $i-1$ and $i-2$, and A, B_1, B_2 are constants determined by least squares fit to past data. The parent escapement for the return in year i was estimated by summing the escapements in year $i-6$, $i-5$, and $i-4$ multiplied by the mean proportion (taken over the years 1965-1982) of the return that were 6, 5, and 4-year-old fish, respectively. These proportions are remarkably consistent from year to year except for cycle years which tend to have more 5-year-old fish returning.

Confidence Limits

Confidence limits were estimated for the accuracy of each of the major forecasting methods (except for the FRI forecast based on purse seine sampling) from analysis of the performance of each of the methods in forecasting past returns to Bristol Bay. A simple linear regression model relating observed return to forecasted returns was fit to past data (Table 1). Confidence intervals around the regression line were estimated by standard techniques (Sokol and Rohlf 1969). The fitted regression line, the 80% confidence interval, and a plot of the historical data are presented for each of the major total Bristol Bay forecast methods (Figures 2 to 5).

RESULTS OF THE ADF&G FORECAST

Presented below is a narrative of the results of the various ADF&G forecasting techniques (Table 2) used to generate river system and age class within river system specific forecasts. Presented for each of the major river systems (Kvichak, Naknek, Egegik, Ugashik, Wood, Igushik, Nuyakuk, and Togiak) are the details of how the forecasts were made, and how, in situations where more than one forecast was available, the several forecasts were averaged or excluded to give the final value. Areas of concern are identified by inconsistencies in results of alternative forecasting techniques. These issues are presented by river system and by age class within river systems. Summaries of forecasts made by return per spawner (R/S) are given in Table 3; forecasts of the return of 4_2 and 5_3 based on return of jacks in 1982 (i.e., using the return of sibling age class forecasting method) are given in Table 4; and forecasts based on smolt data are given in Tables 5 and 6.

Kvichak

Analysis of observed return per spawner since the 1970 brood year has shown that R/S appears to be declining since the 1973 brood year. Returns to the Kvichak were considerably below forecast both in 1981 and 1982. The projected R/S for the 1977 (2.58) and 1978 (1.91) brood years based on returns to date seem to be closer to the average observed historically for the Kvichak system (2.63) rather than the high values observed 1973-1976 brood years (6.04). Consequently we used R/S based on a Ricker escapement-return relationship fit to all years of data since the 1956 brood year.

Table 1. Comparison of various forecast methods, Bristol Bay, Alaska, 1961-1982.

	Predicted Returns in Millions					
		Japanese Sampling[1]		Escapement[2]	Observed Return	
Year	ADF&G[1]	Arithmetic Mean	Geometric Mean	Temperature Model	Inshore	Total
1961	43.6				18.1	23.9
1962	19.9				10.4	11.3
1963	8.6				6.9	7.8
1964	17.4				10.9	11.2
1965	27.8			35.9	53.1	60.0
1966	31.3			18.1	17.5	19.4
1967	13.7			9.1	10.3	11.2
1968	10.4			11.0	8.0	8.8
1969	21.3			23.3	19.0	21.0
1970	55.8			41.9	39.4	43.3
1971	15.2			36.0	15.8	17.8
1972	9.7			9.7	5.4	6.6
1973	6.2	8.9	10.9	4.4	2.4	3.1
1974	5.0	6.8	8.8	9.3	10.9	11.4
1975	12.0	21.1	22.3	19.4	24.2	25.4
1976	12.0	21.9	18.4	18.9	11.5	12.4
1977	8.4	18.9	23.0	8.3	9.7	10.4
1978	11.5	22.4	17.1	13.5	19.9	20.2
1979	22.7	22.1	25.4	41.8	39.9	40.2
1980	54.5	62.1	64.3	63.8	62.3	62.9
1981	26.7	28.4	21.6	34.4	34.5	35.3
1982	34.6	29.2	24.6	18.8	22.2	22.5

[1] Forecast is inshore return.

[2] Forecast is total return, including the estimated Japanese catch.

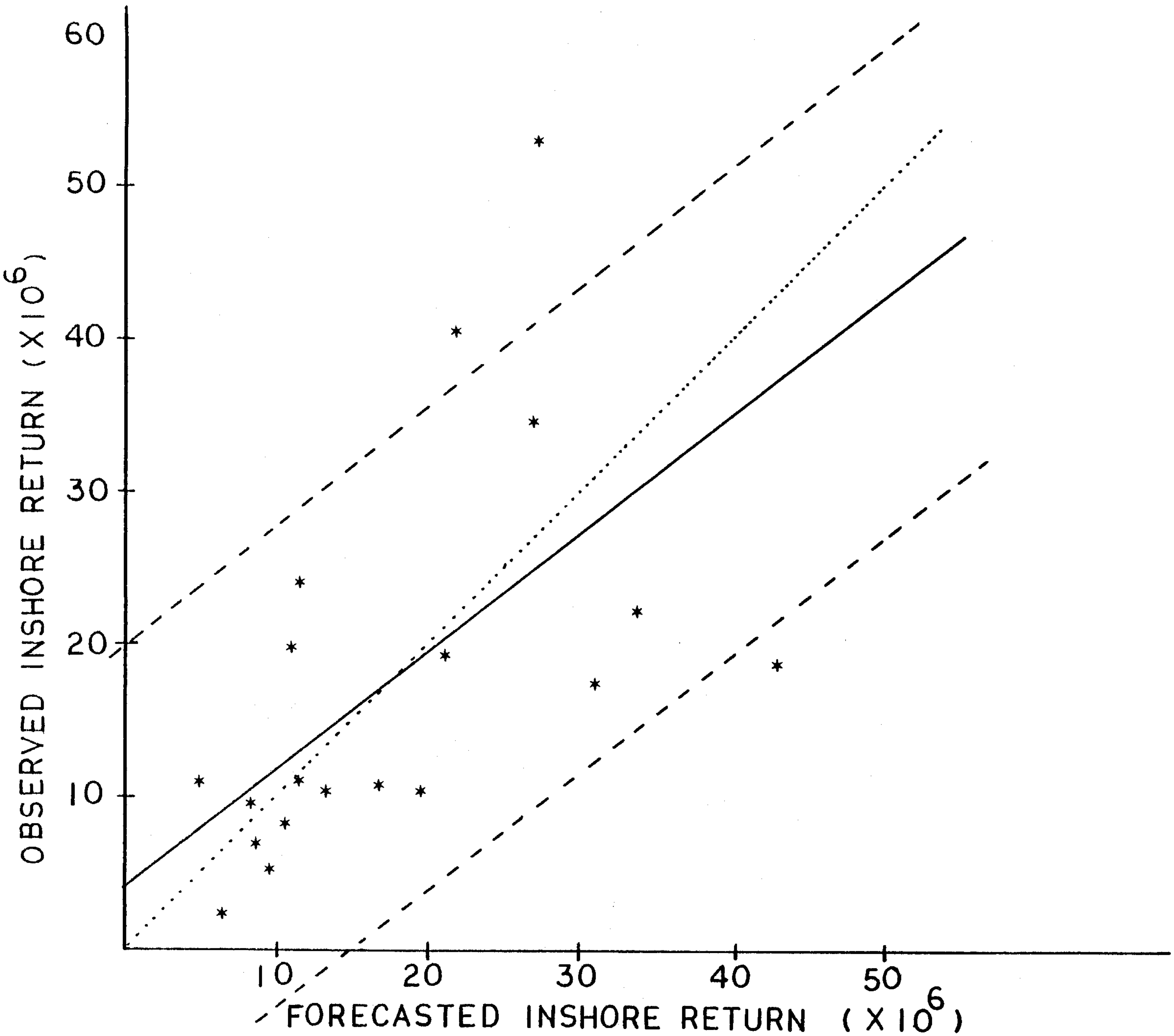

Figure 2. Relation between observed inshore return and forecasted inshore return based on the ADF&G forecasting technique (solid line), together with an 80% confidence band (dashed line). The dotted line is the 1-1 correspondence. $Y = A + BX$, $A = 4.114$, $B = 0.776$, $R^2 = 0.521$, $n = 22$.

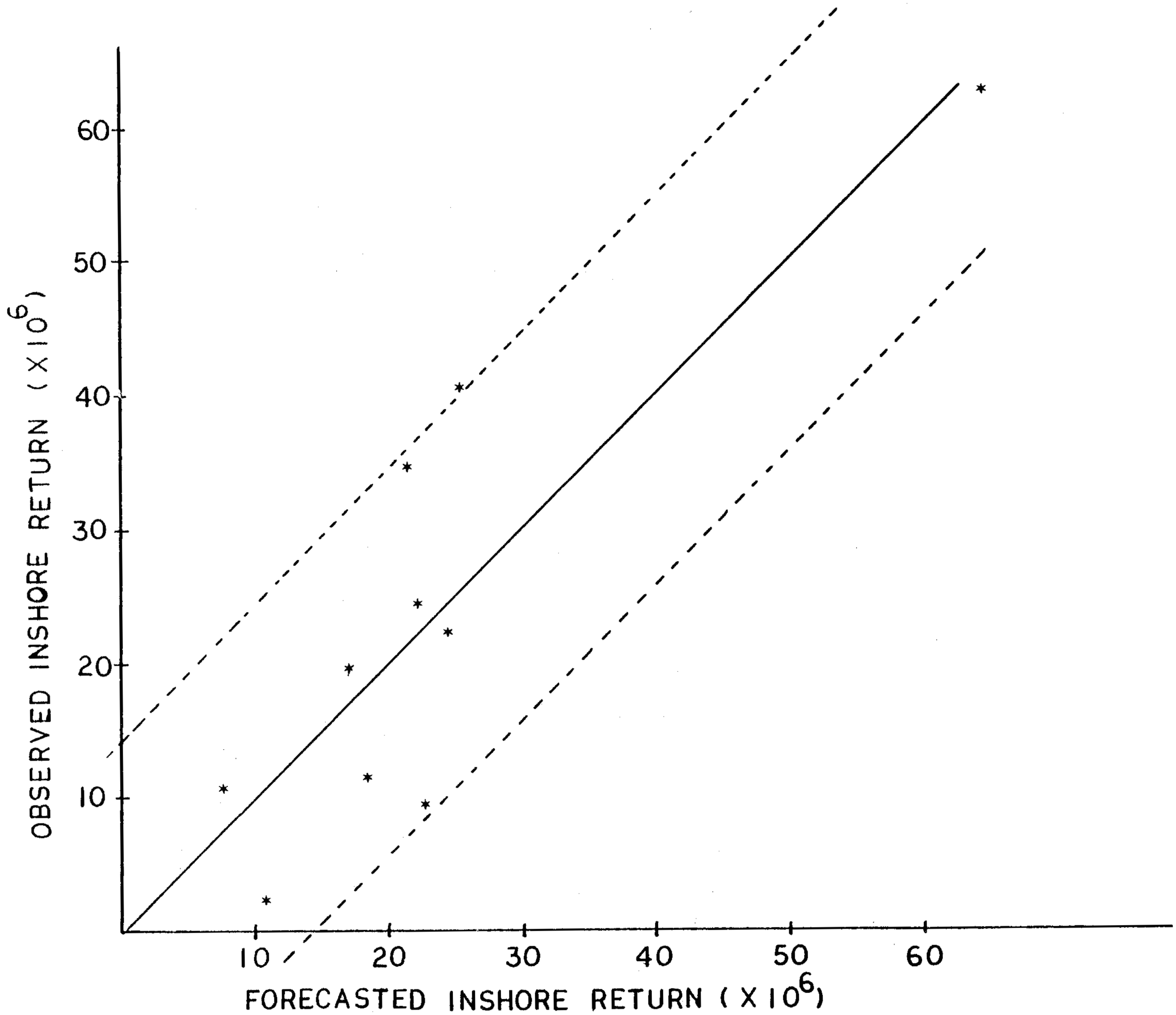

Figure 3. Relation between observed inshore return and forecasted inshore return based on arithmetic mean CPUE from Japanese high seas gill net sampling (solid line), together with an 80% confidence band (dashed line). Y = A + BX, A = 1.033, B = 1.026, R^2 = 0.758, n = 10.

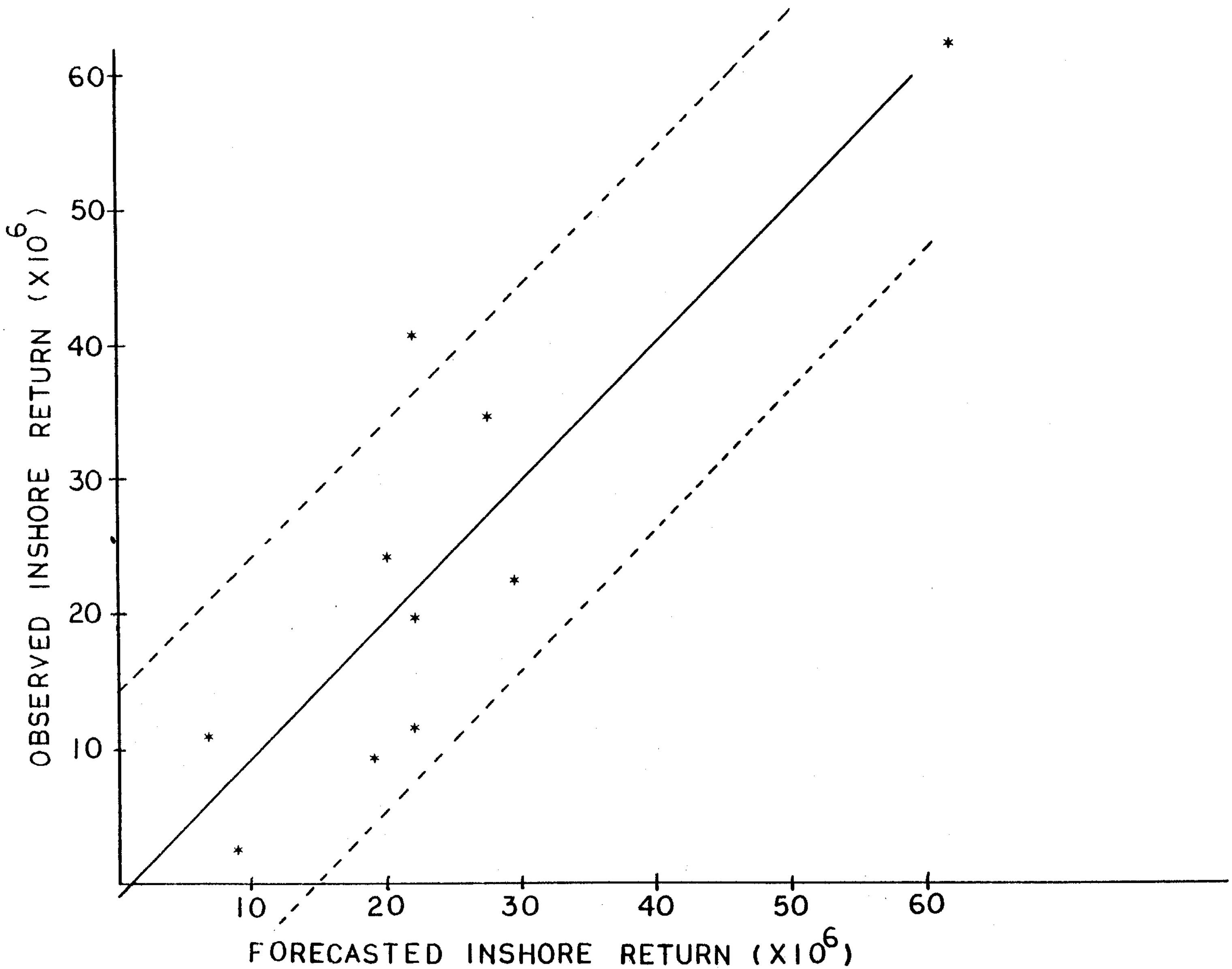

Figure 4. Relation between observed inshore return and forecasted inshore return based on geometric mean CPUE from Japanese high seas gill net sampling (solid line), together with an 80% confidence band (dashed line). $Y = A + BX$, $A = -0.036$, $B = 1.0072$, $R^2 = .749$, $n = 10$.

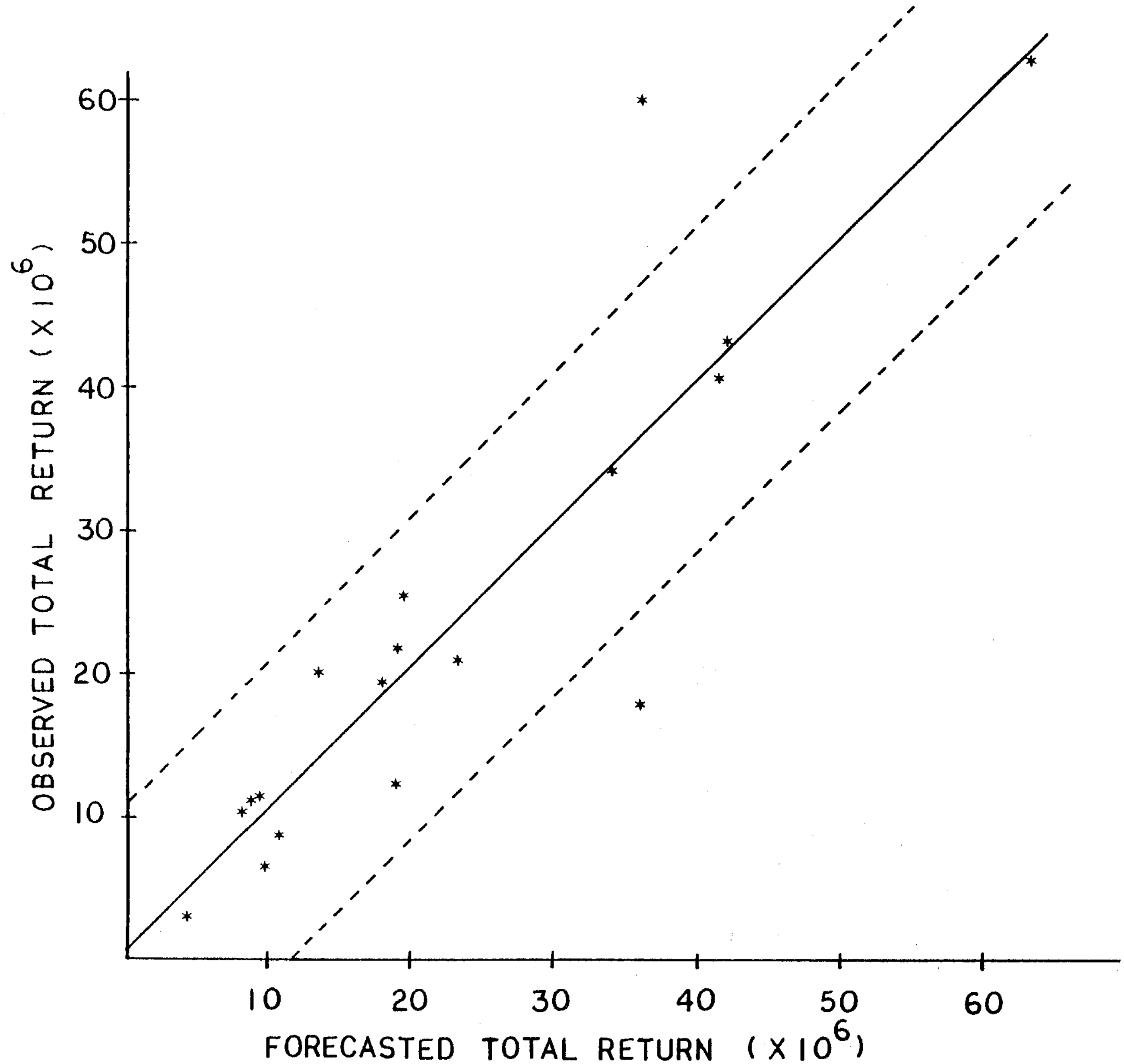

Figure 5. Relation between observed total Bristol Bay returns and forecasted returns based on an escapement - temperature model (solid line), together with an 80% confidence band (dashed line). $Y = A + BX$, $A = 1.077$, $B = 0.989$, $R^2 = .795$, $n = 18$.

Table 2. Preliminary forecast of the 1983 Bristol Bay sockeye salmon run.

District/System	Number of Fish in Thousands				
	Age Class (Brood Year)		Age Class (Brood Year)		
	4_2 (1979)	5_3 (1978)	5_2 (1978)	6_3 (1977)	Total
Naknek-Kvichak District					
Kvichak River	6,616	1,786	962	374	9,738
Branch River	176	97	150	45	468
Naknek River	511	780	949	704	2,944
Total	7,303	2,663	2,061	1,123	13,150
Egegik District	666	1,342	433	974	3,415
Ugashik District	3,305	424	215	233	4,177
Nushagak District					
Wood River	1,647	616	899	94	3,256
Igushik River	153	57	299	131	640
Nuyakuk River	216	81	1,205	84	1,586
Nushagak-Mulchatna	85[2]	--	160	18	263
Snake River	13	8	17	3	41
Total	2,114	762	2,582	330	5,786
Togiak District	172	71	302	44	589
Total Bristol Bay[1]	13,560	5,262	5,591	2,704	27,117

[1] Sockeye salmon of several minor age classes is expected to contribute an additional 1-2 percent to the total return.

[2] Includes 4_1 age class.

Table 3. Summary of forecasts by return per spawner escapements and returns in millions, Bristol Bay, Alaska.

System	Age Class	Parent Escapement	Assumed Return per Spawner	Assumed Prop. of the Respective Age Class in Return	Predicted Return
Kvichak	4_2	11.218	1.66	.253[2]	4.708
	5_3	4.149	1.58	.338[2]	1.079
	5_2	4.149	1.58	.165[2]	2.216
	6_3	1.341	2.58[1]	.225[2]	0.765
Naknek	4_2	0.925	3.87	.138	0.495
	5_3	0.813	3.98	.295	0.956
	5_2	0.813	3.98	.276	0.894
	6_3	1.086	3.72	.276	1.117
Egegik	4_2	1.032	3.13	.063	0.203
	5_3	0.896	3.53	.472	1.493
	5_2	0.896	3.53	.095	0.302
	6_3	0.693	7.17[1]	.311	1.416
Ugashik	4_2	1.701	4.62	.197	1.550
	5_3	0.070	11.66	.460	0.378
	5_2	0.070	11.66	.183	0.150
	6_3	0.201	11.66	.147	0.378
Wood	4_2	1.706	1.86	.481[2]	1.526
	5_3	2.267	1.25	.101	.286
	5_2	2.267	1.25	.402	1.140
	6_3	0.562	5.86[1]	.030	.169
Igushik	4_2	0.860	0.84	.212	0.153
	5_3	0.536	0.84	.126	0.057
	5_2	0.536	0.84	.543	0.245
	6_3	0.096	22.00[1]	.109	0.229
Nuyakuk	4_2	0.360	5.24	.104	0.216
	5_3	0.577	3.88	.036	0.081
	5_2	0.577	3.88	.785	1.756
	6_3	0.233	10.60[1]	.057	0.141
Togiak	4_2	0.171	3.94	.255	0.172
	5_3	0.274	2.44	.106	0.071
	5_2	0.274	2.44	.510	0.302
	6_3	0.134	6.38[1]	.090	0.071

[1] R/S based on returns to date divided by 1 - the long term proportion 6_3 in the return.

[2] Clear cyclic pattern in age composition of return, therefore the mean proportion for the respective cyclic year was used.

Table 4. Summary of Bristol Bay sockeye return forecasts based on returns of jacks in 1982.

	4_2 on 3_2				5_3 on 4_3			
System	Correlation Coefficient	# 3_2 in 1982	Rank	Forecast of 4_2 in 1983	Correlation Coefficient	# 4_3 in 1982	Rank[1]	Forecast of 5_3 in 1983
Kvichak	.402	57,610	0	10,344,536	.898[2]	16,144	3	1,932,737
Naknek	.348	4,421	3	527,578	.501	3,850	13	604,510
Egegik	.928	3,323	1	1,128,532	.694	5,917	5	1,190,806
Ugashik	.818	19,148	0	5,060,239	.508	6,571	3	401,348
Wood	.270	7,748	3	N/A	.606	2,583	4	217,925
Nuyakuk	.315	1,173	1	234,770	N/A[3]	-	-	-

[1] Rank in the # of years since 1956 that have had a higher number of jacks returning.

[2] Cycle years were excluded in the analysis.

[3] No history of 4_3 returning to Nuyakuk.

Table 5. Summary of Bristol Bay sockeye return forecasts made based on smolt studies.

System	Age Class	# Smolt (millions)	Assumed Proportion Returning	Forecast (millions)	Assumed Marine Survival	Assumed Ocean Age Proportion	Forecast (millions)
Kvichak	4_2	162.958	.083[1]	13.569	.0907	.6362[2]	9.403
	5_3	20.653	.104[1]	2.150	.1188	.4623[2]	1.134
	5_2	162.564	.0210	3.417	.0907	.4048[2]	5.969
	6_3	10.110	.0306	.309	.1188	.1201[2]	.144
Wood	4_2	64.330	.0246	1.583	.0589	.5320	2.016
	5_3	33.200	.0407	1.351	.0692	.7720	1.774
	5_2	60.840	.0342	2.081	.0589	.2075	0.744
	6_3	1.993	.0297	0.059	.0692	.6692	0.092

[1] Assumed proportions based on regression of past proportions and mean air temperature June at Port Heiden.

[2] Cyclic ocean age proportions.

Table 6. Summary of Bristol Bay sockeye return forecasts made based on a combination of smolt studies and returns per spawner.

System	Age Class	Assumed Return from Parent Escapement (millions)	Proportion Respective Freshwater Age in Resulting Smolt	Respective Ocean Age Proportion	Forecast (millions)
Kvichak	4_2	18.646	.6444	.6362[1]	7.645
	5_3	6.556	.1127	.4623[1]	.342
	5_2	6.556	.8873	.4048[1]	2.355
	6_3	2.957	.2752	.1201[1]	.098
Wood	4_2	3.173	.9000	.5320	1.519
	5_3	2.834	.4176	.7720	.914
	5_2	2.834	.5824	.2075	.342
	6_3	3.279	.0317	.6694	.070

[1] Cyclic ocean age proportion.

4_2:

There was a large disparity between forecasts made based on smolt data (Table 5 and 6) and the forecast based on R/S. The forecast of 4_2 based on R/S was 4.7 million. Fifty-seven thousand age 3_2 sockeye, the largest 3_2 return ever observed for the Kvichak, returned in 1982. The forecast based on the return of these jacks was 10.3 million. This value was ignored in the final forecast because the record return of 3_2 was beyond the bounds of the data. The three techniques that we used to forecast based on smolt data gave 13.6, 9.4, and 7.6 million. We ignored the first estimate, which was based on the proportion of 4_2 fish returning from the 1981 smolt outmigration estimated from Pt. Heiden June air temperature, because of the failure of that method to predict returns of 4_2 sockeye in 1982. We averaged the two remaining values to give a forecast of 8.5 million based on smolt data. The forecast based on smolt data and R/S was averaged to give the final figure of 6.6 million.

5_3:

The forecast based on return per spawner was 2.2 million. The forecast based on the near record of 4_3 returning in 1982 was 1.9 million. The three techniques used to forecast based on smolt studies gave 2.1, 1.1, and 0.3 million. The most inconsistent was the latter figure which was based on a combination of R/S and the observed three year old component of the smolt produced from the 1977 escapement. We averaged the three smolt forecasts giving a 1.2 million figure. The values from each of the three major forecasting techniques were averaged to give the final figure of 1.8 million.

5_2:

The forecast of 5_2 (1.1 million) based on R/S was consistent with the forecast (0.8 million) based on return of 4_2 in 1982. That latter forecast was based on an average of 1.1 million from regression of 5_2 on 4_2 and 0.6 million from cyclic ratio of 5_2 to 4_2. However, these forecasts were widely inconsistent with the forecast (3.9 million) based on smolt data. That forecast was an average of 3.4, 6.0, and 2.4 million given by the three techniques used to forecast from smolt data. The large smolt forecast was ignored in the final figure because of the failure of the 1980 smolt migration to return as 4_2 in 1982. The forecast based on R/S and return of 4_2 were averaged to give the final figure of 1.0 million.

6_3:

The final figure of 0.4 million was an average of the forecast based on R/S (0.8 million), based on return of 5_3 in 1982 (0.2 million), and based on smolt data (0.2 million).

Kvichak Synopsis

A heavy return of 4_2 is forecasted for the Kvichak in 1983. This was based on a very conservative interpretation of the data in view of the lower than anticipated return to the Kvichak in 1981 and 1982. The return of 3_2 in 1982 and the smolt data suggest a much larger return. This is a key area to watch in 1983.

A moderate return of 5_2 is forecasted to return in 1983 based primarily on the lower than forecast return of 4_2 in 1982. One can speculate that the low return of 4_2 was due to delayed maturation. If this were to occur or if we were to have normal proportions of the large 1980 smolt outmigration to return as 5_2, then the return of 5_2 could be much higher in 1983. The Bristol Bay staff felt that this was unlikely to occur because the returns of 5_2 and 4_2 from the same brood year are closely related in the Kvichak. The poor return of 4_2 in 1982 suggests that the return of 5_2's in 1983 will be poor to moderate. 5_2's have never been a dominant component of the Kvichak return. It would be very unusual for 5_2's to return in sufficient numbers to mediate the very low marine survival based on the returns thus far from the 1980 smolt outmigration. Nevertheless, this is another key area to watch in 1983.

Naknek

The observed return per spawner since the 1970 brood year has ranged from 1.79 to 6.01. There does not appear to be any decreasing trend in return per spawner over time in the Naknek system. There is a slight depression in R/S at high escapements. The escapements in 1977, 1978, 1979 were moderate and the assumed R/S for these escapements are 3.72, 3.98, and 3.87, respectively. These are based on simple linear regression of R/S against escapements for the 1970-1976 brood years.

4_2, 5_3, and 5_2:

The forecast based on R/S and that based on return of sibling age classes were very consistent for each of these age classes. The final forecasts of 0.5 million 4_2's, 0.8 million 5_3's, and 0.9 million 6_3's, are a simple average of these two forecasts.

6_3:

There was inconsistency in the forecast based on R/S (1.1 million) and the forecast based on the very low return of 5_3's in 1982 (0.3 million). The final forecast was an average of these two numbers. This inconsistency, however, points to a key area to watch in the Naknek in 1983. The forecast (0.7 million) will either be under or over depending on whether the return of 6_3's to the Naknek is strong or weak.

Egegik

Observed R/S since the 1969 brood year has ranged from 1.34 to 9.87. There is a clear decrease in R/S with increasing escapement. Escapements over 1 million have produced R/S less than 3. There is a decreasing trend in R/S since the 1976 brood year but this is related to an increasing trend in escapement since 1976. The assumed R/S for the 1977, 1978, and 1979 brood years are 7.17, 3.53, and 3.13, respectively. These are based on simple linear regression of R/S on escapement for the 1969-1976 brood years.

4_2:

There was a great inconsistency in the forecast based on R/S (0.20 million) and the forecast of 1.1 million based on the near record return (3.3 thousand) of 3_2 in 1982. The final forecast (0.7 million) was the average of these two values. This would be an unusually large return of 4_2 to Egegik. Limited sampling of the 1981 smolt outmigration from Egegik showed that 2-year-old smolt were 37 percent of the population. This was the highest observed in the 7 previous samples taken during the years 1956-1978, which averaged 15% 2-year-old smolt. The final forecasted value for the return of 4_2 to Egegik in 1983 represents a compromise between the very large forecast based on return of 3_2 and the very low forecast based on the historically low proportion of 4_2 returning to Egegik. This is a key area to watch in 1983.

5_3:

The forecast based on return per spawner (1.5 million) was nearly identical to the forecast based on a large return of 4_3's in 1982 (1.2 million). If the return of 4_2's is strong in 1983 and the limited smolt age composition data taken in 1981 is correct the return of 5_3's to Egegik in 1983 could be much stronger than the 1.3 million forecast. This is another key age class to watch in 1983. We should watch very carefully the early age composition data in Egegik as there is a potential for a very large return to Egegik in 1983.

5_2:

The forecast based on return per spawner (0.30 million) and the forecast based on return of 4_2's in 1982 (0.56) were averaged to give the final forecast of 0.43 million.

6_3:

There was inconsistency between the forecast based on R/S (1.4 million) and the forecast based on the poor return of 5_3's in 1982 (0.53 million). The return of 5_3's was the lowest since 1973. The final forecast (0.97 million) was an average of these two values. This inconsistency and the large forecasted return of 6_3's points to another area to watch in 1983.

Ugashik

Return per spawner has been very high in the Ugashik system since the 1974 brood year. The projected R/S for the 1977 and 1978 brood years based on returns to date is 12.8 and 16.1, respectively. The range of R/S since 1974 has been 9.16-14.4, with the mean for those years being 12.47. The parent escapements for the 1977, 1978, and 1979 brood years that will contribute to the 1983 return are 0.2, 0.070, and 1.7 million, respectively. The major problem in making the 1983 Ugashik forecast is estimating the R/S from the large 1979 escapement. There is a decreasing trend in return per spawner with increasing escapement. A linear regression model was used to extrapolate R/S for the high 1979 escapement, giving a value of 4.6. The average R/S observed for the 1975-1976 brood years (11.7) was used to forecast returns from the 1977 and 1978 brood years.

4_2:

There was a very large inconsistency between the forecast based on R/S (1.6

million) and the forecast based on the record return of 3_2's in 1982 (5.1 million). The final forecast value (3.3 million) was simple average of these two numbers. If this were to occur it would be a record return of 4_2 to Ugashik. The previous high return was 3.1 million 4_2's in 1960. The forecast based on R/S was based on a fairly conservative (4.5) R/S relative to those observed in very recent years. However, the parent escapement for the 1983 4_2 return was very high and it is possible that density dependent mortality due to those high escapements will cause a return of 4_2's lower than forecast. This is a key area to watch in 1983, as actual returns will probably be significant above or below forecast levels.

5_3, 5_2, 6_3:

The final forecast of 0.4 million 5_3, 0.2 million 5_2, and 0.2 million 6_3 were simple averages of the forecast based on R/S and forecast based on return of younger sibling age classes. The two forecasts were very consistent for 5_3's and 5_2's. The forecast of 6_3 returns based on R/S (0.38 million) was much larger than the forecast based on the return of 5_3's in 1982 (0.09 million).

Wood River

Observed R/S from the 1970-1976 brood years ranged from 1.49-6.49. Projected R/S for the 1977 and 1978 brood years based on returns to date if 5.9 and 1.1, respectively. The escapement in 1978 was 2.3 million. This is the largest observed to that time, (note that the escapement in 1980 was higher). There is a clear decreasing trend in R/S with increasing escapement. The projected R/S for the 1978 brood year is consistent with that trend. The natural logarithm of R/S was regressed against escapement, giving values of 4.07, 1.27, and 1.86 for R/S for the 1977-1979 brood years, respectively.

4_2:

Nearly 7.7 thousand 3_2's returned to Wood River in 1982. But the relation between 4_2 and 3_2 returns is very poor for the Wood River system; consequently, the return of 3_2's in 1982 was not used in the forecast. The forecast based on R/S (1.5 million) was very close to the forecast based on smolt data (1.8 million). These were averaged giving 1.6 million as the final forecast of 4_2's returning in 1983.

5_3:

There was a large inconsistency among the forecast based on R/S (0.29 million), the forecast based on return of 4_3's in 1982 (0.22 million) and the forecast based on smolt data (1.3 million). A good return of 4_3's to Wood River occurred in 1982. The forecast based on return of 4_2's was low due to historically low return of 5_2's to Wood River. The forecast based on smolt data was very high due to a very large percentage of 3-year-old smolts (34% compared to 5.7% average for the previous years of data), as well as a high estimated level of 3-year-old smolt abundance (33 million compared with 6.4 million average for the previous years of data). The final forecast (0.60 million) was a simple average of these 3 values. Because of the inconsistency in the forecasts and the fact that the age composition of the 1981 smolt outmigration was unusual, this is a key area to watch in 1983. It is likely that the return of 5_3's to the Wood River system will be higher than forecast.

5_2 and 6_3:

The forecasts based on R/S, smolt data, and return of sibling age classes were fairly consistent for these age classes. The final forecast (0.90 and 0.09 million for 5_2 and 6_3, respectively) were simple averages of these 3 forecasts.

Igushik

Observed R/S from the 1970-1976 brood years has ranged from 0.90 to 15.96. The projected R/S for the 1977 and 1978 brood years based on returns to date is 22.0 and 0.46, respectively. The escapements in 1977 and 1978 were markedly different, with the escapement in 1977 being 0.096 million and 0.54 million in 1978. There is an almost precipitous decrease in R/S with increasing escapement in the Igushik system. The escapement in both 1978 and 1979 were very high. The escapement in 1979 was 0.86 million, which was a record to that date. R/S observed for past escapements near or exceeding 0.5 million were less than 1.0 and averaged 0.84. That value was used to project returns from the 1978 and 1979 brood years.

4_2 and 5_3:

The Igushik system produces almost no jacks; consequently the method based on return of jacks is not available to forecast returns of 4_2's and 5_3's. The forecast based on R/S for 4_2 and 5_3 is 0.15 and 0.057 million, respectively.

5_2:

The forecast based on R/S was 0.25 million, whereas the forecast based on the return or 4_2's in 1982 was 0.35 million. The final forecast was 0.30 million.

6_3:

The forecast based on R/S was 0.23 million, while the forecast based on the low return of 5_3 in 1982 was 0.032 million. The final forecast (0.13 million) was an average of these two values.

Nuyakuk

The Nuyakuk returns have been dominated by 5_2's in recent years. The assumed age composition of the return by brood years were taken to be in the mean of observed values 1967-1976 brood years. Observed R/S from 1970-1976 brood years has ranged from 2.34 to 17.74. The projected returns from the 1977 and 1978 brood years based on returns to date is 10.6 and 1.74, respectively. There is a slight decreasing trend in R/S with increasing escapement, especially if the projected R/S for the 1978 brood year is considered. Linear regression of the natural logarithm of R/S against escapement gave predicted R/S for the 1978 and 1979 brood years of 3.88 and 5.24, respectively. The value predicted for the 1978 brood year is considerably greater than the value based on the returns to date (i.e., the return of 4_2's in 1982 divided by the long term mean proportion of 4_2's expected from any given brood year escapement). The forecasted returns from 4_2, 5_3, and 6_3 were 0.22, 0.081, and 0.084 million, respectively. The 4_2 and 6_3 forecasts were averages of the forecasted return based on R/S and the forecasted return based on return of sibling age classes in 1982. The Nuyakuk produces no 4_3 jacks, consequently the forecast of 5_3's was based on R/S.

5_2:

The forecasted return of 5_2 was 1.2 million and was an average of the forecast based on R/S (1.75 million) and the forecast based on return of 4_2 in 1982 (0.65 million). The forecast based on R/S is based on an assumed R/S of 3.9 for the 1978 brood year. This value is considerably greater than that for the 1978 brood year projected from the limited return of 4_2's in 1982. The return of 5_2's in 1983 could be lower than forecast. Because of this and the fact that 5_2's are such a large component of the Nuyakuk system, this a key area to watch in 1983.

Togiak

Observed R/S from the 1968-1976 brood years has ranged from 1.77 to 7.42. The projected returns from the 1977 and 1978 brood years based on returns to date is 6.38 and 1.56, respectively. There is a decreasing trend in R/S with increasing escapements, particularly if the low projected R/S for the 1978 brood year is considered. A linear regression model of R/S and escapement level fitted to data from the 1968-1978 brood years gave estimated R/S from the 1978 and 1979 brood years of 2.44 and 3.94, respectively. Togiak produces very few jacks (both 3_2 and 4_3) consequently forecasts based on their return were not available. The forecasts for return of 4_2, 5_3, 5_2, and 6_3 were made based on R/S or an average of the forecast based on R/S and returns of sibling age classes in the case of 5_2 and 6_3. Those forecasts are 0.17, 0.071, 0.30, and 0.044 for 4_2, 5_3, 5_2, and 6_3, respectively.

SUMMARY AND CONCLUSIONS

The forecasts for the 1983 return of sockeye salmon to Bristol Bay made with the available methods ranged from 26.3 to 43.5 million fish (Table 7). In addition to the four methods detailed above the Fisheries Research Institute has made a forecast of the 1983 return based on limited sampling in 1982 with purse seine in the old FRI high seas sampling and tagging area in the North Pacific Ocean south of Adak. That forecast was 20 million (D.E. Rogers, Fisheries Research Institute, University of Washington, Seattle, personal communication). Confidence intervals were also computed (Table 7). The best forecast technique, in terms of that with the narrowest confidence intervals, is the forecast based on the escapement-temperature model. The worst is the standard ADF&G forecast (Table 7). These results must be qualified because the ADF&G forecast is made based only on past data, whereas the other forecast procedures utilized all years of data to "hind cast" the past. In view of this, the variability of the ADF&G forecast is expected to be higher.

Table 7. Summary of available forecasts of 1983 return of sockeye salmon to Bristol Bay.

Forecast Method	Standard Deviation about Model (millions)	Forecasted Return (millions)	80% Confidence Interval	
			Lower Bound	Upper Bound
Standard ADF&G	11.8	27.1	9.5	41.7
Japanese gill net sampling mean CPUE	9.3	36.2	21.9	50.2
Japanese gill net sampling geometric mean CPUE	9.5	43.5	28.2	59.4
Escapement temperature model	8.2	26.3	15.0	37.6
Purse seine sampling at Adak	?	20.0	?	?
Average weighted by inverse of standard deviation[1]	-	33.36	-	-

[1] FRI Adak forecast not included due to low magnitude of sampling intensity in 1982 relative to past levels.

A synopsis of key areas to watch as the run emerges in season in 1983 is provided in Table 8. These are particular age classes that are likely to be large components of the run in each of the constituent river systems. In most cases there are inconsistent forecasts by alternative ADF&G methods. A departure from the forecasted age composition is a clear indication of error in the forecast and careful monitoring of the early age composition of the run should provide suitable warning if this should happen in 1983.

Forecasts by age class are available for the forecast based on geometric mean CPUE from gill net sampling by the Japanese and for the forecast based on purse seine sampling off Adak (Table 9). There is a striking consistency in the ocean age composition of all forecasts. The forecasted return is dominated by 2-ocean fish. There is some inconsistency, however, in the freshwater age component of the 2-ocean fish. Both of the forecasts based on high seas sampling give a higher proportion of 5_3 returning from the ADF&G forecast. The geometric mean Japanese forecast gave a very large return of 5_3 (15.9 million). If this were to occur, the ADF&G forecast would likely be much lower than the actual return. It is useful to address the question of to which river systems would a large return of 5_3's go. Based on the ADF&G exercise those fish would most likely return to Wood River, Kvichak, and Egegik. The forecast of the 5_3 return to Wood River based on smolt data was 1.3 million, compared with the final forecast of 0.61 million. The unusual age composition of the 1981 smolt outmigration in Wood River suggests that the return of 5_3's could be substantially higher than forecast. For the Kvichak there was a relatively low percentage (11.2%) of 3-year-old smolt in the 1981 outmigration. If the return of 5_3 is much higher than forecast then this would suggest a good survival of that outmigration and the return of 4_2's would be higher than forecasted.

The only other system where one could see a large return of 5_3's is Egegik. There is a large 2-ocean return to Egegik (2.0 million) forecasted. The proportion of 3-year-old smolts based on limited sampling of the Egegik population in 1981 is 63%. If the ADF&G forecast of 4_2's is correct and 5_3 and 4_2 return in proportion observed in the smolt samples the return of 5_3 to Egegik would be 1.8 million compared with the forecasted value of 1.3 million.

If the high seas forecasts turn out to be correct we are going to see substantially higher returns of 4_2's to Kvichak, Egegik, Wood River, and Ugashik and 5_3's to Kvichak, Egegik, and Wood River. The age structure for these systems should be carefully monitored in the 1983 season.

Table 8. Key areas to watch in 1983 where forecast is likely to be in error. Synopsis summarizing inconsistencies among forecasting techniques.

System	Age Class	Forecast (millions)	Synopsis	Departure from Forecast
Kvichak	4_2	6.6	High smolt, record return of 3_2 in 1982, Kvichak has not produced well in 1981 or 1982.	Higher return
	5_2	1.0	Poor return of 4_2 in 1982, high smolt.	Unknown
	5_3	1.8	Large 5_3 component in high seas forecasts, low smolt.	Higher return
Naknek	6_3	0.7	High R/S, low return.	Unknown
Egegik	4_2	0.7	Historically low proportion 4_2 returning. Good return of 3_2, consistency in limited smolt data.	Unknown
	5_3	1.3	Large 5_3 component in high seas forecast, consistency in limited smolt data, good return of 4_3.	Higher return
Ugashik	4_2	3.3	Very large parent escapement, little comparable R/S data available, record return of 3_2.	Unknown
Wood	5_3	0.6	Historically low proportion 5_3, high smolt, good return of 4_3, large 5_3 component in high seas forecast.	Higher return
Igushik	All age classes	0.6	A low R/S assumed for high parent escapements.	Higher return
Nuyakuk	5_2	1.2	High R/S, moderate return of 4_2.	Lower return

Table 9. Total Bristol Bay forecast by major age classes for each of the alternative forecast methods.

Forecast Technique		4_2	5_3	Total 2-ocean	5_2	6_3	Total 3-ocean	Total
Standard ADF&G	Numbers (millions)	13.5	5.3	18.9	5.6	2.7	8.3	27.1
	Percent	49.8	19.5	69.3	20.7	10.0	30.7	
Japanese sampling geometric mean	Numbers (millions)	17.6	15.9	33.5	8.4	1.6	10.0	43.5
	Percent	40.5	36.6	77.0	19.3	3.6	23.0	
FRI sampling	Numbers (millions)	9.8	5.2	15.0	4.3	0.7	5.0	20.0
	Percent	49.0	26.0	75.0	21.5	3.5	25.0	